STAT

Next 1 Page(s) In Document Denied

Sanitized Copy Approved for Release 2011/04/08 :
CIA-RDP81-00280R000200030035-5

STAT

## EQUIPMENT OF A 24-CHANNEL MULTIPLEX TELEPHONE SYSTEM USING SYMMETRICAL LINE CABLES (K-24)

(Conclusion: For Beginning See No 5, 1953)

Vestnik Svyazi /Communication News/, No 6, 1953, Moscow, Pages 3-6

G. G. Borodzyuk, Candidate Technical Sciences, Stalin prize laureate
G. N. Stepanov, engineer, Stalin prize laureate
A. V. Cheremetev, Candidate of Technical Sciences

### LINE AMPLIFIERS AND DEVICES FOR AUTOMATIC REGULATION OF THE TRANSMISSION LEVEL

The most important and the most widely used units of the K-24 apparatus, utilized in all the terminal and intermediate stations, are the line amplifiers, which compensate for the attenuation of the line sections in the line spectrum of the apparatus from 12 to 108 kc. These amplifiers satisfy very rigid requirements with respect to many of their parameters and particularly with respect to non-linear distortion, noise, accuracy with which the frequency characteristics are corrected, and reliability of operation. The need for satisfying the above requirements is due to the fact that the group path of the apparatus, the currents of 24 channels, are being subjected to simultaneous amplification; in addition, a large number of amplifiers may be connected to a single carrier-channelized circuit, inasmuch as an average of 30 amplifiers is used for each 1,000 km in each direction.

Line amplifiers of the following types are used in the K-24 apparatus: amplifier without ALR, amplifiers with flat-sloping ALR, and amplifiers with flat-sloping-curvilinear ALR.

Amplifiers with flat-sloping ALR are used both at flat-sloping intermediate stations, as well as at intermediate stations intended only for flat ALR. In the latter case the sloping automatic level regulation are switched into the amplifiers manually when necessary, and sloping ALR receivers are not installed.

Amplifiers with flat-sloping-curvilinear ALR are also used in the reception channel of the terminal stations; in this case they are called reception amplifiers. In addition, among the line amplifiers one can also include the transmission amplifiers, operating at the output of the transmission channel of the terminal stations. Even though the transmission amplifiers cannot be called line amplifiers in the full sense of the word, nevertheless they approximate the latter, because they work in the same frequency range and must satisfy the same requirements as line amplifiers with respect to many principal parameters; transmission amplifiers differ principally only in that they have a flat amplification characteristic.

In their principal portion, namely the amplifier element proper, all the above-mentioned line amplifiers are identical and differ from each other only in the external negative feedback chain and in the correction networks connected at the input of the amplifier element. The amplifier element proper contains three stages employing 10Zh1L tubes in the case of local supply and 12Zh1L tubes in the case of remote supply. To increase the power two tubes connected in parallel are used in the output stage.

STAT

Special recently-developed tubes (type 12Zh3L) used for remotely-fed repeaters have all the characteristics of the 12Zh1L tube, but have a considerably higher breakdown voltage in the cathode-filament portion. Inasmuch as the filaments of the remotely-fed amplifier tubes in both directions of transmission are connected in series, the operating voltage between the cathode and the filament of the tube nearest to the line is approximately 100. If the filament circuit of the tube should be opened (for example, whenever one of the tubes is removed), the voltage may rise to the maximum value used in remote supply (240 volts). Therefore, to increase the operative reliability of the connection, as the production of the 12Zh3L tube expands, it is necessary to change over from 12Zh1L to 12Zh3L tubes in the line amplifiers of the remotely-fed points. The above applies equally well to other remotely-fed repeater stations of multi-channel apparatus, namely to the intermediate stations of the K-12 system and to the VUS-12 stations.

A simplified diagram of a line amplifier with flat-sloping-curvilinear ALR is shown in Figure 5. Heavy negative feedback is used in the amplifiers to insure the required attenuation of the non-linearity and the required stability of gain whenever the voltage of the power supply fluctuates and whenever tubes are replaced. Two types of feedback are used: external interstage and internal in the first and third stages. The external feedback and the internal feedback in the third stage are of the combined current and voltage type, while current feedback is used in the first stage.

It follows from examination of Figure 5 that the amplifier differs in its diagram from the line amplifier of the K-12 apparatus with respect to the interstage coupling circuits, which contain also induction coils in series with the active plate load resistors. More substantial differences are in the external negative feedback chain and in the networks connected at the input of the amplifier. Placed in the negative feedback chain are: constant slope network CSN, corresponding to a line section 8 km long, a set of lengtheners having a total attenuation of 1.3 nepers (in steps of 0.1 nepers each), a flat regulation device, "flat LR." with limits of ± 0.5 nepers at 16 kc, as well as a network for regulating the curvilinearity, "curv. LR," with limits of ± 0.25 nepers at 64 kc.

Connected at the input of the amplifier are filter K-12 and 5 line equalizer networks LE, which slope the frequency characteristic of the gain so as to correspond to line sections 12, 6, 3, and 1.5 km in length (a total of 28.5 km), and also a potentiometer that permits adjusting the gain within limits of 2.7 nepers, in steps of 0.3 nepers each.

The maximum gain of the amplifier at the highest frequency of 108 kc when the level regulating devices are in the central position is 8 ± 0.1 nepers. This gain is changed automatically when the cable attenuation is changed by temperature with the aid of the ALR device. Manual regulation is also possible, effected in this case by changing the position of contact-making jumpers.

Because they contain fewer regulating elements, amplifiers with flat-sloping ALR and without ALR have a correspondingly simpler feedback chain. The constant slope network in amplifiers with flat-sloping ALR corresponds to a line section 14.5 km long, while in amplifiers without ALR corresponds to a length of 20 km. At the input of these amplifiers there is a set of line equalizers, corresponding to line sections 12, 6, 3, and 1.5 km in length (a total of 22.5 km). The maximum gain of the amplifier without ALR is 8.3 ± 0.1 nepers, and that of an amplifier

STAT

with flat-sloping ALR with the regulating elements in the central position is 8 0.1 nepers. All the values of section length given above pertain to cables with paper-kordel' insulation.

Automatic level regulation devices intended for compensation of temperature variations of the cable attenuation characteristics are analogous in the K-24 apparatus with the same devices used in the K-12 apparatus. The regulation is carried out without the aid of electromagnetic mechanisms, by changing the resistances of indirectly heated thermistors TR-1 -- TR-3, operating in the feedback chain of the line amplifiers. Control is effected by control-frequency current, received by the control-channel receivers. The basic difference lies in the introduction of a third automatic regulation, namely curvilinearity regulation, intended for compensation of the deviation of the increment in frequency characteristic of the cable attenuation from a straight-line law. The need for this regulation is considerably greater in the case of the K-24 apparatus than in the case of the K-12 apparatus, owing to the expanded frequency spectrum. The curvilinear regulation is controlled with a 64 kc control current, while the flat and sloping regulations are controlled with 104 and 16 kc respectively.

The circuits of the control channel receivers of the K-24 apparatus differ from those of the K-12 apparatus of the first versions in the addition of a device that reduces considerably the operating process of the level regulation, which occurs whenever several amplifiers with ALR are connected in series and the level at the start of the trunk line changes suddenly. At the present time this modification has also been effected in the control-chamber receiver circuits of the K-12 apparatus.

## CONSTRUCTION AND GROUPING OF APPARATUS: CURRENT CONSUMPTION

The K-24 apparatus is similar in its construction to the K-12 and V-12 apparatus. Many racks in the terminal stations are identical with the racks of the K-12 apparatus. Among such racks are: the tonal-calling rack (STV), differential-system rack (SVS), four-wire switching rack (SChK), individual converter rack (SIP), carrier and control frequency rack (SNK), remote-supply transmission rack (SDP-1), cable-circuit test and signalization rack (SKTs), and lead-in and switching rack (VKS), used whenever line transformers are used for the carrier-channelized pairs at an expanded frequency range up to 110 kc. The dimensions and the capacities (depending on the number of channels served by the equipment) of these racks are indicated in the description of the K-12 apparatus.

In addition, the terminal station comprises also the group-installation rack of the 24-channel system (SGU). It has overall dimensions of 646 x 2,500 x 450 mm, which is standard for long-distance communication apparatus racks. Placed on the SGU rack are the transmission and reception amplifiers, the group frequency converters, the automatic level regulation devices, and other elements of the group channel used for 2 24-channel systems.

The repeater stations comprise the SDP-1, SDP-II, SKTs, and VKS racks, which are identical with the racks of the K-12 apparatus. The SDP-I and SKTs racks are used only for attended stations, and the SDP-II are used only in unattended stations. The attended stations also contain intermediate-repeater racks SPU with amplifiers without ALR, with flat ALR, with flat-sloping ALR, and with flat-sloping-curvilinear ALR, depending on the type of the stations. The unattended stations are equipped with SPU racks without ALR and with remote supply.

STAT

All the amplifier racks have overall dimensions of 646 x 2,500 x 450 mm. With this, the racks without ALR, those with flat ALR, and those with flat-sloping ALR carry equipment for 5 systems, while the rack with the flat-sloping-curvilinear ALR is equipped for 3 systems. The terminal stations may be equipped with artificial lines, the attenuation characteristic of which is equivalent to the attenuation of cables 8 and 14 km long. These lines are used if the repeater section is of shortened length.

The voltage of the power supplies of the terminal stations should be stabilized with an accuracy of ± 3%. The power supplies of the attended intermediate stations should also be stabilized. The following minimum voltages at the output of the stabilizing devices have been established for the apparatus: plate voltage, 206 ± 3%; filament voltage, 21.2 ± 3%.

The remote-supply current is stabilized automatically by voltage regulators on the SDP-I rack, with an accuracy of ± 3%. The nominal known voltage applied to the amplifiers in the remotely-supplied points is 160.

The average current consumption for the rack of the K-24 apparatus required to supply the filament and plate circuits of the tubes and also for the principal signalling circuits, is indicated in the table.

| Designation of Rack | Current consumption, amperes | | Remarks |
|---|---|---|---|
| | Filament battery | Plate battery | |
| STV | 5.80 | 0.22 | For one 24-channel system |
| SChK | 0.64 | 0.01 | For one rack (up to 60 channels) |
| SIP | 3.80 | 0.17 | For two racks (one 24-channel system) |
| SGU | 1.20 | 0.13 | For one 24-channel system |
| SNK | 7.70 | 0.50 | For one rack (up to five 24-channel systems) |
| SKTs | 0.25 | - | For one rack |
| SPU with flat ALR | 0.64 | 0.08 | For one 24-channel system |
| SPU with flat-sloping ALR | 0.90 | 0.12 | For one 24-channel system |
| SPU with flat-sloping-curvilinear ALR | 1.16 | 0.15 | For one 24-channel system |
| SPU without ALR, remotely fed | - | 0.13 | For one 24-channel system |
| SPU without ALR, locally fed | 0.40 | 0.05 | For one 24-channel system |

## DESIGN OF PLACEMENT OF REPEATER POINTS

The maximum rated gain of the intermediate stations of the K-24 apparatus is 8.2 nepers. However, it does not follow from this that all the repeater sections may have an attenuation equal or nearly equal to



Sanitized Copy Approved for Release 2011/04/08 : CIA-RDP81-00280R000200030035-5

STAT

8.2 nepers, for in this case the noise level in the channels will be excessive. To keep within the norm for the psophometric noise voltage in the channels, the attenuation of the repeater sections should be on the average 7 nepers, and only in individual sections can it reach 8 to 8.2 nepers.

The locations of the repeater points (RP) are determined during the design in the following manner. Starting with the average value of attenuation, one obtains the rated length of the repeater section, which is: 32 to 34 km for a cable with paper-kordel' insulation and 37 to 39 km for a cable with styroflex-kordel' insulation. The proposed trunk line is then subdivided into repeater sections, taking into account the need of placing the RP in populated points and adhering as much as possible to the rated length. The maximum permissible length of a repeater section cannot exceed 39 km for a cable with paper-kordel' insulation and 46 km for a cable with styroflex-kordel' insulation. The correct placement of the repeater points must be checked against the expected value of the psophometric voltage of the intrinsic (broadband) noise in the channel. The latter must not exceed 0.5 millivolts (at a point with a relative level of -0.8 nepers) for a re-reception section 2,500 km long. If the re-reception length of the section is less, the norm for the magnitude of the intrinsic noise in the channel can be determined from the following inequality:

$$U_{n\ intr} \leqslant 0.5\sqrt{L/2500}\ \text{millivolts}$$

where L is the length of the re-reception section in km. The above norm corresponds to the accepted distribution of noise, in accordance with which one quarter of the power, out of the norm for all types of noise (1 milliwatt for 2,500 km) is allotted to the intrinsic (broadband) noise in the channel.

The psophometric voltage of the intrinsic noise is the voltage measured with a psophometer in the channel in the absence of transmission over the other channels of the system and over the channels of the same name of the parallel systems. The expected value of the psophometric voltage of the intrinsic noise in the upper channel, which is under the worse condition, is calculated from the following equation:

$$U_{n\ intr} \approx 0.05\sqrt{\sum_{i=1}^{i=N} e^{2\Delta S_i}}$$

where i is the number of the repeater section; N the number of repeater sections; $\Delta S_i$ the difference between the gain of the repeater station and the average gain ( $\Delta S_i = S_i - 7$); 0.05 the psophometric noise voltage introduced into the channel by a single repeater station with a gain of 7 nepers.

(/Note/: The number 0.05 applies when the transmission power level in the upper (24th) channel is + 0.5 nepers, i.e., when the transmission level has a sloping frequency characteristic; if the characteristic is horizontal and the transmission power level is + 0.2 nepers, it is necessary to substitute 0.07 for 0.05 in the equation.)

The value of the gain is determined by the following equation:

$$S_i = \beta_{(108)} l + \Delta \beta_{t(108)} l',$$

where $l$ is the length of the repeater section in km; $\beta_{(108)}$ the per-kilometer attenuation of the cable at 108 kc and at minimum temperature, given in nepers per kilometer; $\Delta\beta_{t(108)}$ the change in the

STAT

per-kilometer attenuation of the cable at 108 kc when the temperature changes from the maximum to the minimum, given in nepers per kilometer; $l'$ the distance from the preceding amplifier with ALR, given in km.

From the equations given it follows that to check the noise level by calculation it is necessary to know within what range the soil temperature changes at the depth at which the cable is laid (0.8 m) and to specify the placement of the point that are equipped with amplifiers with ALR. For the majority of the regions of the European portion of the USSR it is possible to assume that at a depth of 0.8 m the soil temperature fluctuates over the year from -4 degrees to +16° C.

The change in the per-kilometer attenuation of the cable is determined from the following equation:

$$\Delta\beta_t = \beta_{t1}\alpha_\beta \ (t_2 - t_1)$$

where $\beta_{t1}$ is the per-kilometer attenuation at the minimum temperature, $\alpha_\beta$ the temperature coefficient of attenuation, $t_1$ the minimum temperature, and $t_2$ the maximum temperature. If the cable has paper-kordel' insulation with star twist and conductors 1.2 mm in diamter (copper), then the temperature coefficient $\alpha_\beta$ for 108 kc is found to range from $6 \times 10^{-4}$ to $8 \times 10^{-4}$ per degree. For a cable of this type $\beta_{(108)} = 205 \times 10^{-3}$ nepers/km and $\Delta\beta_{t(108)} = \pm 3^{-3}$ nepers/km.

The placement of the points equipped with amplifiers with ALR is made on the basis of the regulation limits and of the value of $\Delta\beta_t$. The maximum distance between points with flat ALR can be obtained from the following expression.

$$l'_{max\ (flat)} = \frac{0.7}{\Delta\beta_{t(108)}} \approx 230 \text{ km}$$

In practice it is recommended that amplifiers with flat ALR be placed closer, so as to obtain a certain margin to provide for the inaccuracy in the initial level setting and for the inaccuracy in the initial data concerning the temperature fluctuations. Usually in the design each third or fifth repeater point is equipped with amplifiers with flat ALR.

The limiting distance between points equipped with amplifiers with flat-sloping ALR is determined from the following equation:

$$l'_{max\ (flat/sloping)} = \frac{1}{\Delta\beta_{t(16)} - \Delta\beta_{t(108)}}$$

where $\Delta\beta_{t(16)}$ is the temperature variation in the per-kilometer attenuation of the cable at the control frequency of the sloping regulation, i.e., at 16 kc.

For a cable of the above type and for the above-mentioned temperature-fluctuation limits we have $\Delta\beta_{t(16)} \approx 5 \times 10^{-3}$ nepers/km, and the maximum distance between points can be assumed to be approximately 500 km. Points equipped with amplifiers with flat-sloping ALR are located in practice every 10-12 repeater sections, i.e., 300-400 km apart. Amplifiers with ALR should be installed in points that are equipped with independent sources of supply. One does not compute the limiting distance for points equipped with amplifiers having flat-sloping-curvilinear ALR; such points must be placed approximately every 800-1,000 km.

STAT

To determine the location of the amplifier points with ALR in the case of trunk lines equipped with cable with styroflex-kordel' insulations, it is necessary to find the coefficients $\Delta\beta_{t(108)}$ and $\Delta\beta_{t(16)}$ corresponding to the projected cable.

When locating the repeater points it is necessary to take into account that the maximum gain of 0.2 nepers can be used only between points equipped with amplifiers without ALR. The maximum attenuation of a repeater section (at the minimum temperature), adjacent to a point equipped with ALR, must not exceed 7.5 nepers. Consequently, the maximum permissible length of such a section is 36.5 km for a cable with paper-kordel' insulation and 42 km for a cable with styroflex-kordel' insulation.

When the calculations are made one must bear in mind that reducing the gain in short repeater sections results in noise improvement. This improvement can be taken into account only when regulating the gain in the feedback chain. The limits of this regulation are restricted to a minimum value of 6.8 nepers for amplifiers with ALR and 5.5 nepers for amplifiers without ALR. Thus, if the value of $\beta_{(108)}l$ obtained during the calculation of the gain ($S_1$) is less than the above, the value of $\beta_{(108)}l$ should be assumed to be 6.8 or 5.4 nepers respectively.

The noise levels in the channels were measured during the line and operating tests of the K-24 apparatus, performed on an experimental section of the trunk line. With this the measured values agreed with the calculated ones, obtained with the above equations. The difference between the measured and calculated values did not exceed 10%.

## RESULTS OF EXPERIMENTAL OPERATION

Experimental operation of the apparatus has shown that the channels of the K-24 system have high qualitative indexes and satisfy all requirements that are imposed on telephone channels of trunk lines. As a whole the apparatus works reliably with a minimum number of breakdowns.

At the same time, certain shortcomings of the apparatus also became apparent. Among them are: (1) high sensitivity of the ALR devices to sudden changes in control-frequency levels, resulting in fluctuations in the residual attenuation whenever the level of the control frequency drops or changes suddenly for a short period; (2) complexity of the circuit and too low stability in the operation of the carrier and control frequency generating equipment; (3) impossibility of remotely feeding three repeater points in a row; (4) individual insufficiently developed structural items.

Work is being carried out at the present time on the improvement of the apparatus, to eliminate the above shortcomings. In particular, the problem is being solved concerning the subdividing the automatic-regulation sections into subsections with blocking and unblocking of the control frequency, so as to reduce the effect of short-time changes in its level on the operation ALR devices.

STAT

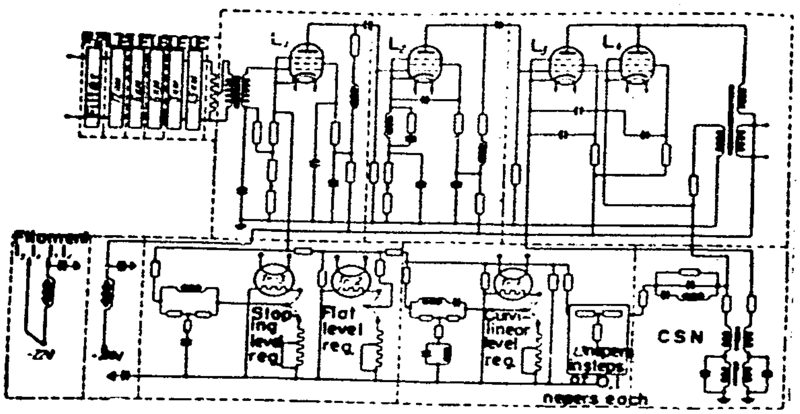


Figure 5

* * *